May 3, 2004

To: Dr. Dave Starr (912)

From: Frank Schmidlin (972)

Subject: CODE 972 AIRS VALIDATION REPORT

The Upper Air Instrument Research Project (UAIRP) of the Observational Science Branch (Code 972) in the Laboratory for Hydrospheric Processes proposed to provide validation measurements from ozonesondes, from chilled mirror-sondes (SNOW WHITE), and from the Accurate Temperature Measuring radiosonde for use of the Atmospheric Infrared Sounder (AIRS) on the AQUA satellite. Validation measurements were originally proposed to be obtained from Wallops Flight Facility (37.8N; 75.5W), and would be a series of concentrated measurements during one month of every quarter throughout the year. This would allow 8-12 observations of each sonde type each quarter. Funds were provided to procure the expendables and additional instrument components as necessary. The Principal Investigator (F. J. Schmidlin) presented the UAIRP proposal to a meeting of the AIRS Science and Validation Team Members responsible for the analysis and the in situ and/or ground-based measurements. This meeting, hosted by Jet Propulsion Laboratory in Pasadena, California in November 2001, provided a great opportunity to interact with everyone involved with the AIRS mission and ultimately resulted in a revised look at the needs of the validation program.

After discussions, it was indicated that validation measurements from a number of different locations were desirable. Individual validation profiles from the larger number of sites would help to detail AIRS algorithm development. The sample sizes that could be obtained at each site selected would be less than the number of samples estimated from only Wallops Island. However, surrounding this modification to the original proposal was the advantage of the greater geographical distribution of the validation measurements. Financially, conducting validation measurements from more than one site could be accomplished by judicious rescheduling of the available resources to meet personnel and equipment needs. The resources to be made available, unfortunately, did not allow a large number of field locations to be included. Thus, AIRS validation requirements for transportation and manpower were leveraged to other activities that were occurring coincidently to the same time periods. Validation measurements from various sites are still continuing through this current spring, and measurements from Wallops Flight Facility will continue through the end of the current fiscal year. We'd like to continue this effort for one more year; however, the NRA for additional work issued in January 2003 was missed. Additional dialogue concerning this will be addressed later in this report.

Following the launch of AQUA in May 2002 and the turn-on of the AIRS instrument, in situ validation measurements were scheduled from Wallops Island, Andenes, Norway (69 N: 16E), Andros Island, The Bahamas (24N;72W), Natal, Brazil (6S; 35W), Ascension Island (8S; 14W) and ESRANGE, Sweden (68N; 21E). The Andoya Rocket Range,

Andenes, Norway was included because of the planned Space Sciences sounding rocket campaign called Mountain and Convective Waves Ascending Vertically Experiment (MaCWAVE). Dr. R. A. Goldberg (Code 690) and F. J. Schmidlin (Code 972) were investigators in this Code S mission to obtain rocket measurements for the purpose of studying the generation of gravity wave activity. The campaign presented an opportunity to leverage the cost of the personnel needed in Norway and Sweden, making the AIRS validation data gathering cost effective. MaCWAVE was a two-part campaign. Part 1 took place in Norway in July 2002 (radiosondes and rocketsondes) and, part 2 took place in Norway (radiosondes only) and in Sweden (radiosondes and rocketsondes) in January 2003. Regular radiosonde types were flown in Norway and Sweden and chilled mirrors only in Norway. Because of the high latitude involved sufficient overpasses of AIRS occurred each day enabling a balloon release close to the most desirable orbit. Four standard radiosonde profiles and five SNOW WHITE (chilled mirror) profiles from Norway were delivered to the JPL-AIRS archive files. Coincidently, rocketsondes launched for MaCWAVE also coincided with AIRS ephemeredes allowing eight Falling Sphere temperature profiles to be delivered to JPL, as Table 1 indicates.

Observations obtained in January 2003, from ESRANGE included only standard radiosondes and Falling Spheres. Chilled mirrors were not considered because those observations made from Norway were considered to be close enough geographically to satisfy the AIRS overpass distance, and would have been redundant in any case. Nonetheless, 13 Falling Sphere profiles from 35 km to 85 km are available for delivery to the archive as well as 16 radiosonde profiles, also indicated in Table 1.

Another site of opportunity was the US Navy's Atlantic Undersea Test and Evaluation Center (AUTEC) facility on Andros Island, The Bahamas. Arrangements were completed with the US Navy in July 2002, for the use of AUTEC. This site was used on two previous occasions for the Convection and Moisture Experiments, CAMEX 3 and CAMEX 4. The facility is located in the sub-tropics, about 200 kilometers southeast of Miami, FL and is relatively free of commercial air traffic allowing validation schedules to be easily met, and, except for the occasional hurricane, the site can be used for measurements 24 hours a day. The major difficulty associated with obtaining Navy permission for use of Andros Island was the problem of balloon debris falling into the nearby waters and possibly endangering sea turtles. The balloon we use is made of latex and eventually biodegrades. Earlier, we received permission from the Navy to conduct the CAMEX 3 tests on the basis that there did not exist documentation describing the effect on sea turtles if ingesting latex. The Navy's position was that CAMEX 3 would, hopefully, provide some information after their crews surveyed the local ocean. After releasing 132 balloons during CAMEX 3 and 256 balloons during CAMEX 4 the Navy scavenging teams did not find pieces of balloon material in the nearby ocean, nor did they find any expended radiosondes. This is unusual because we know that 40 percent (155) of the instruments did not fall on the island. Because of this negative experience, the US Navy permitted us to return to AUTEC to obtain validation measurements for AIRS. Two technicians spent a few days setting up equipment in August 2002, but returned to Wallops because of the shut down of the AIRS instrument. After their return to Andros Island, the first validation flight was made on September 14 2002. The Andros Island site

validation measurements are cost effective due to the low lodging cost because of the availability of Navy housing, and three meals per day obtained from the on site cafeteria.

Measurements from Andros Island included Electrochemical Concentration Cell (ECC) ozonesondes and SNOW WHITE chilled mirror instruments. Data from nine ozonesondes were submitted to the JPL-AIRS archive. In addition, 12 SNOW WHITE chilled mirror data sets also were delivered to the archive. Figure 1 gives an example of dew point temperature and relative humidity measured with the SNOW WHITE instrument. Weather conditions at AUTEC are not extreme, winds are usually light and cloud cover is of the typical sub-tropical types. On occasion heavy cumulus will inhibit releasing a chilled mirror instrument. The SNOW WHITE does not care for water clouds that saturate the mirror sensor with an overabundance of water. This contamination gives false readings.

An agreement established between NASA and the US Air Force at Patrick AFB in 1998 permitted ozonesondes to be released weekly from Ascension Island. This was accomplished as part of the Southern Hemisphere Additional Ozone project (SHADOZ). The AIRS validation requirement resulted in our supplementing the launch program at Ascension while maintaining the SHADOZ requirement. The weekly balloon release time is adjusted to coincide with AIRS ephemeredes. Only daytime observations are possible. Fifty-nine successful ozonesonde flights were made between June 2002 and March 2004. Table 1 shows valid observations through December 2003.

Sixty-one ozonesondes have been flown from Natal, Brazil since October 8, 2002. The Instituto de Pesquisas Espaciais (INPE) of Brazil and NASA have had agreements to release ozonesondes for a number of years. The recent agreement was signed in 1998 for a 10-year period. The agreement has been useful because it has permitted weekly ozonesondes for studying ozone depletion, the SHADOZ Project, and now for AIRS validation measurements. The INPE Natal, personnel are very competent and with their cooperation we have been able to obtain many data sets. In addition to the ozonesondes, INPE agreed to release SNOW WHITE chilled mirrors at the time of AIRS overpass. Eighteen SNOW WHITE chilled mirrors were delivered to Brazil last year. According to the launch personnel, there have been many low clouds that have inhibiting releasing these instruments each week. It is expected this situation will be rectified during the dry seasons.

Validation measurements from Wallops Island are progressing well. Eighty-one ozonesondes and 20 chilled mirrors have been flown. These data are in the JPL-AIRS archive. Unfortunately, only 4 Accurate Temperature Measuring (ATM) radiosondes were flown. The reason for so few observations has been the concentration on ozone and water vapor. The number of ATM radiosondes will be increasing over the next few months. The ATM radiosonde is able to give temperature accuracy in the stratosphere of 0.2°C-0.3°C. This technology is presently being used by the National Weather Service to validate new radiosondes obtained through recent procurement. After reviewing the validation measurement history it is apparent that our data needs to be exploited further in conjunction with AIRS. I will be pursuing this with JPL (Eric Fetzer).

During the AIRS Science Team meeting at Camp Springs, MD on February 25-27, 2003, it was shown that the validation data were being well utilized. There were some misconceptions about some of the Wallops profiles, but these were cleared up rapidly. The meeting also reminded me that we (UAIRP) should also begin comparisons between the retrieved AIRS data and our validation measurements. At the Science Team meeting, it was mentioned by Dr. Moustafa that validation data from high latitudes were very much needed. Because our rapport with the ranges in Scandinavia is good we contacted the Andoya Rocket Range in Andenes, Norway in May 2003 to determine their interest in supporting a program of balloon-borne SNOW WHITE chilled mirror observations. The cost estimate was reasonable and acceptable and after adding a task to a Sounding Rocket Program contract already in negotiation with Norway we, in February 2004, initiated weekly, or more often, chilled mirror measurements. The first chilled mirror was released on February 5$^{th}$, 2004 and it is expected that a minimum of 20 observations will be obtained. The number of flights presently available is now 14. Figure 2 is an example of one flight measurement obtained in early March. We also had the opportunity to use the ARM facility at Barrow, AK.

During October/November 2003, we participated in the AWEX tests at the Atmospheric Radiation Measurement site (ARM) in Oklahoma along with the Raman Lidar operated by Dave Whiteman's group, the NOAA Frost Point Hygrometer operated by Holger Vömel, and Vaisala radiosondes operated by Barry Lesht. As part of our contribution to the AWEX test, 21 Intermet radiosondes and 10 Chilled Mirror radiosondes were released. Data are still under evaluation by the AWEX team. One profile example comparing the chilled mirror with the Frost Point hygrometer is shown in Figure 3. Other comparisons are available. The Wallops-obtained data coincident with AIRS overpass is to be sent to the JPL-AIRS archive.

A final note, five AIRS-coincident chilled mirror water vapor measurements were obtained from Barrow, AK (71N) during March 2004. This was part of a test taking place at the North Slope ARM site in cooperation with NOAA (Ed. Weatherman) and DOE. (Ted Cress).

Table 1. List of observations made to validate AIRS. Delivery to the JPL-AIRS archive is still being conducted.

AIRS VALIDATION MEASUREMENT STATUS
June 23, 2002 – March 31, 2004

| | WAL | NAT | ASC | ASD | ANX | ESR | Total |
|---|---|---|---|---|---|---|---|
| Ozonesonde | 81 | 61 | 59 | 9 | | | 210 |
| Chilled Mirror | 20 | 1 | | 12 | 19 | | 52 |
| Rocketsonde | | | | | 8 | 13 | 21 |
| ATM Radiosonde | 4 | | | | | | 4 |
| Radiosonde | * | * | * | * | 4* | 15 | 19 |
| Total Observations | 105 | 62 | 59 | 21 | 31 | 28 | 306 |

ASC Ascension Island
ASD AUTEC, Andros Island, the Bahamas
ANX Andoya Rocket Range, Andenes, Norway
ESR ESRANGE, Kiruna, Sweden
NAT INPE, Natal, Brazil
WAL Wallops Island, VA

* NOTE: If there was an ATM radiosonde, ozonesonde, or chilled mirror measurement available, the typical radiosonde measurements are implied.

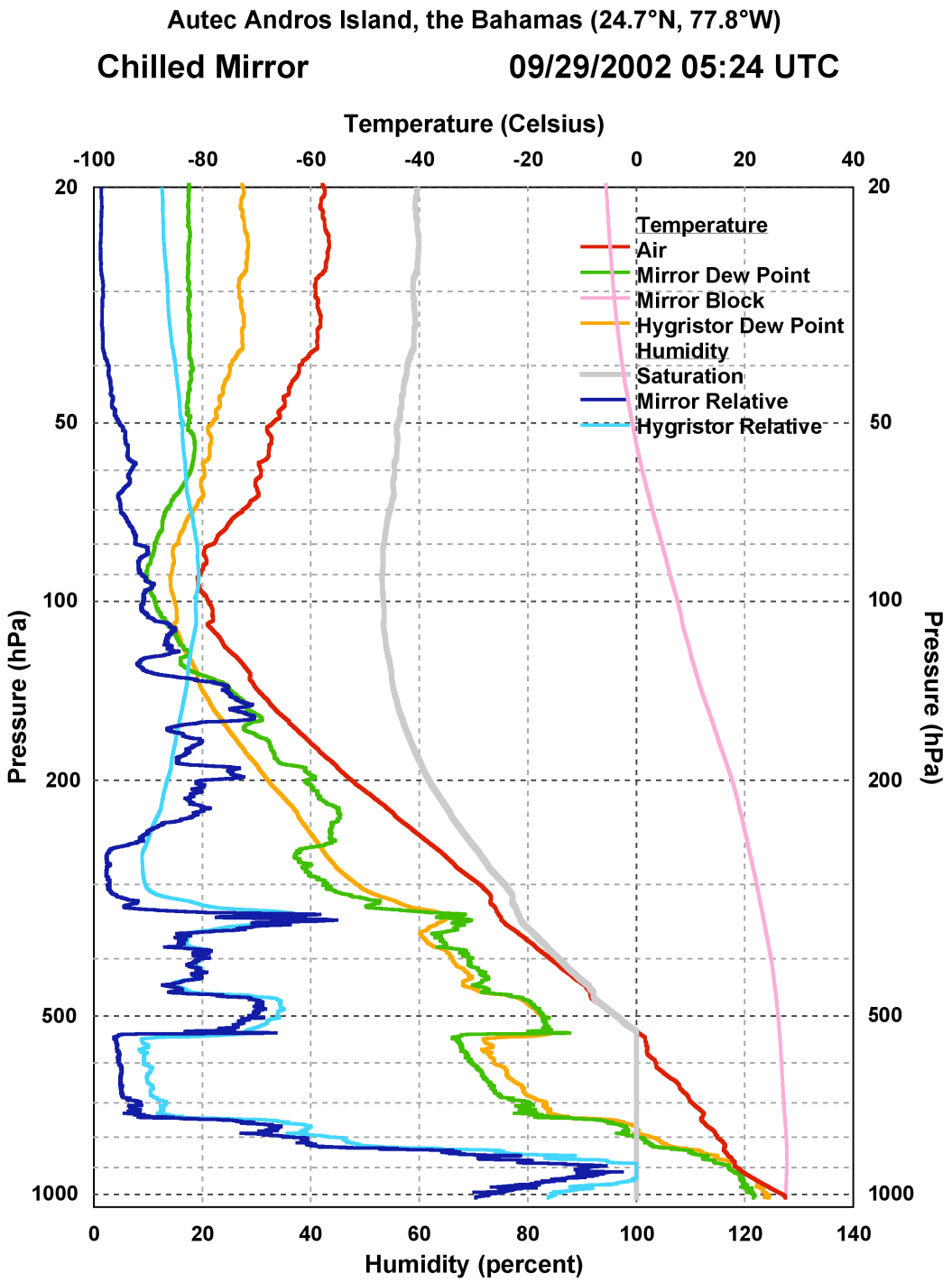


Figure 1. Example of data from a SNOW WHITE chilled mirror flown from Andros Island, The Bahamas in September 2002. The important information to note is: the response of the chilled mirror dew point (mirror temperature) to the cirrus cloud layer near 150 hPa; the rapid response of the dew point; the structure not observed by the standard radiosonde sensor at 300 hPa and at lower pressures. The chilled mirror's response is relatively fast as the structure shown suggests.

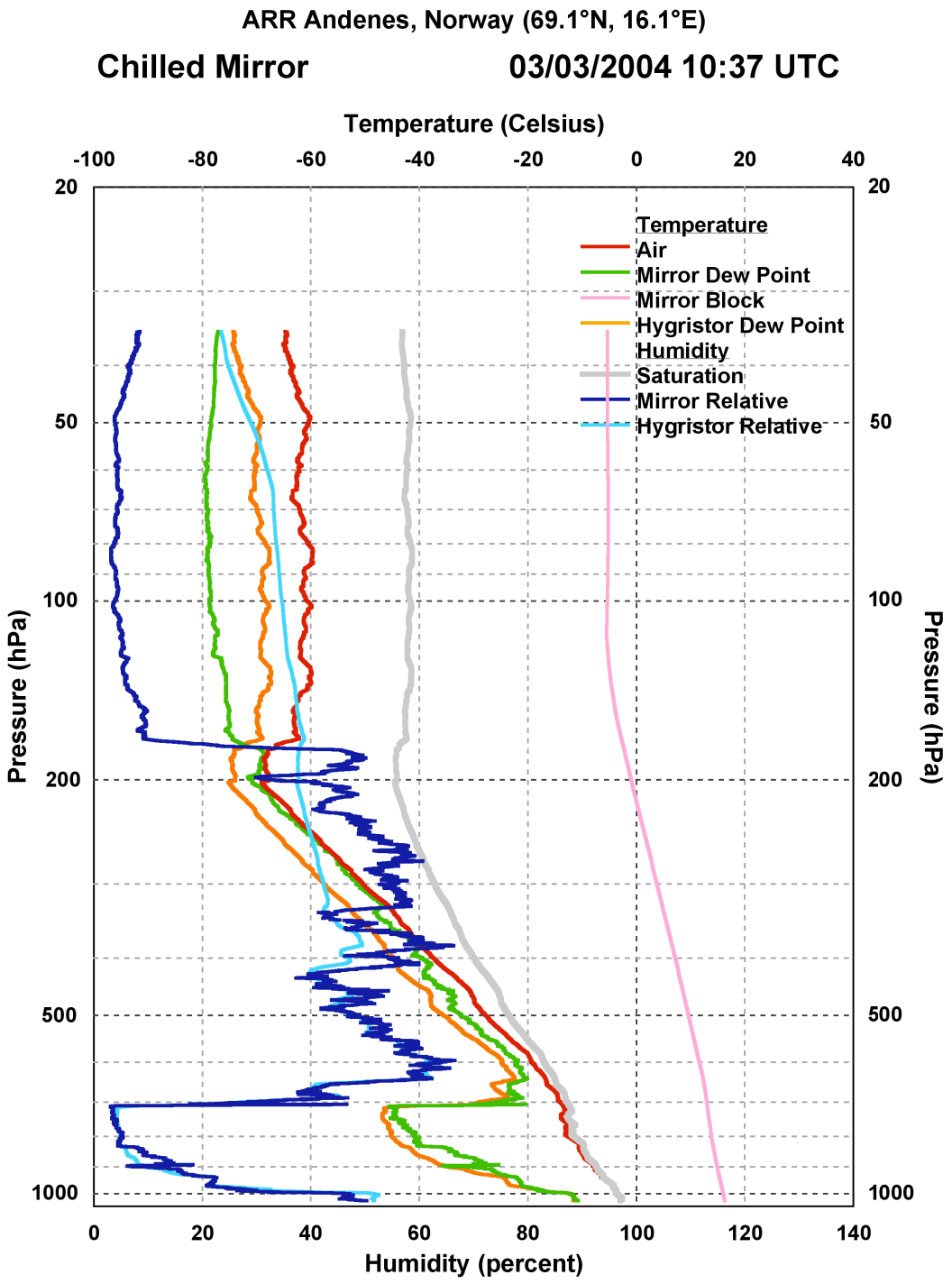


Figure 2. Chilled Mirror measurement from ARR, Andenes, Norway on March3. 2004. ambient temperature at instrument release was –4C and the air was dry as indicated by the profile of the chilled mirror and the Sippican hygristor. The chilled mirror reveals structure in the RH profile not seen by the hygristor at pressures lower than 400 hPa.

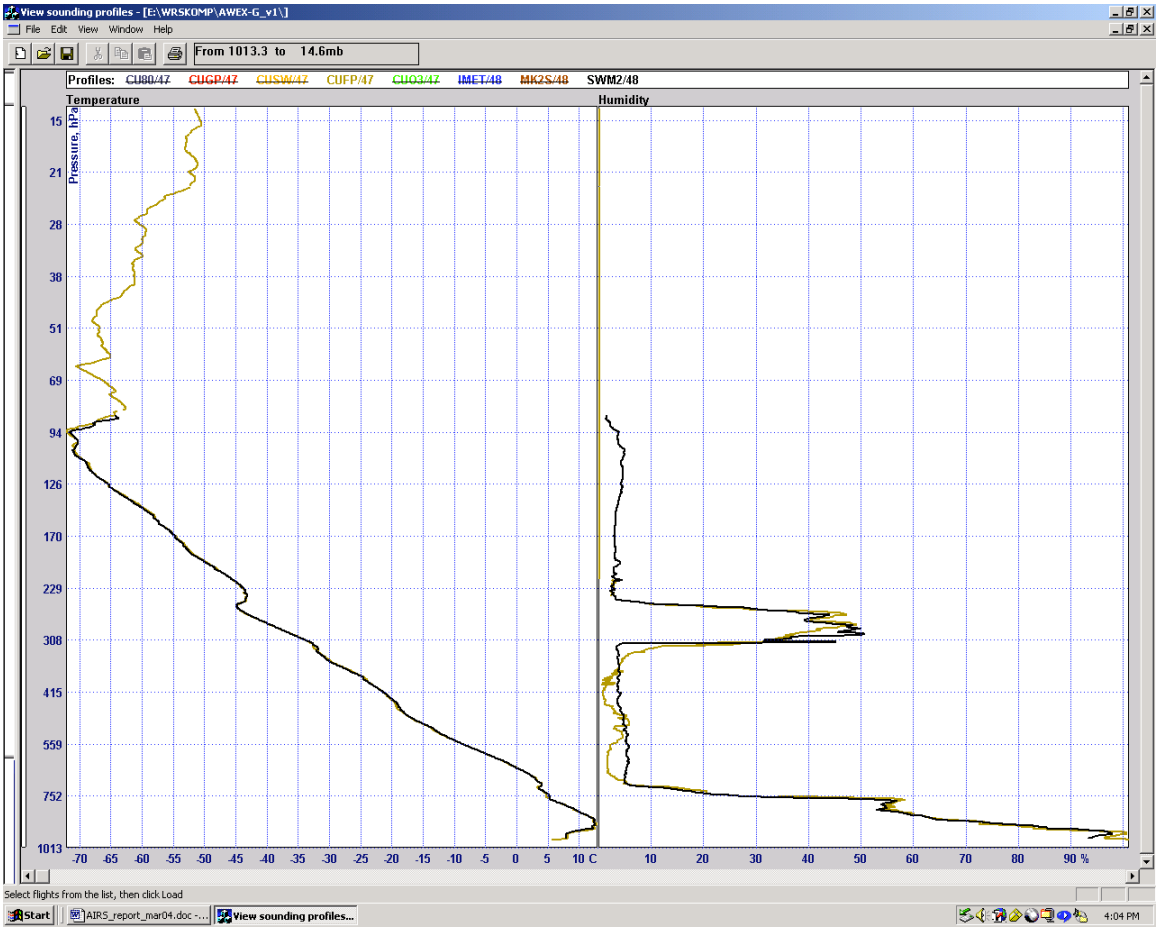


Figure 3. One test flight obtained at the Southern Great Plains ARM site on November 15 2003 at 0816 UTC. A SNOW WHITE chilled mirror (black) is compared with the NOAA Frost Point Hygrometer.